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ABSTRACT

This paper describes Arthur, a World Wide Web-based instruction system that provides adaptive instruction to accommodate learning style in order to achieve a significant difference when technology is applied to instruction. The design of Arthur is discussed, including considerations related to the learning experience, adapting instruction, and learner models using case-based reasoning. System implementation is then described, including the client side, the server side, and the Intelligent FAQ (Frequently Asked Questions) information retrieval system. (Contains 18 references.) (MES)

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Arthur: Adapting Instruction to Accommodate Learning Style

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Abstract: The theory of learning styles states that people have different approaches to learning and studying (Dunn 1987 & Dunn 1978). Given a specific instruction method or environment, some people will learn more effectively than others due to their individual learning style and the grade distribution of the learning would be bell shaped, with the majority of the learners appearing in the middle of the distribution curve. Several studies show that there is "No Significant Difference" when technology is applied to instruction (Russell 1999), since either in traditional classrooms or in any of the technological environments, there is only one form of instruction, and usually from one source, yielding the familiar bell shaped grade distribution. This explains the "No Significant Difference" results and indicates that another instruction method needs to be investigated. An approach to achieve "A Significant Difference" is to provide several different instruction methods. This paper describes Arthur, which is a Web-based instruction system that provides adaptive instruction to achieve "A Significant Difference".

Introduction

Learning styles are approaches to learning and studying (Dunn 1987). We all have learning preferences, which enable us to learn more effectively. When introduced into a learning environment that supports our learning style(s), learners have a higher level of understanding the material. The learning styles theory implies that how much individuals learn has more to do with whether the educational experience is geared toward their particular style of learning. In a traditional classroom environment, there is one instructor and several learners, which is an one-to-many relationship. The instructor presents information with his/her personal style of instruction. The instructor may use technology such as overhead slides, computer animations, videos, or simply chalk and talk lectures. If the instructor's style of instruction is conducive with the majority of the learner's learning style, then the class as a whole will perform well. In the general case, the instructor's style is conducive with most of the learner's, but not a perfect match. In this case, the majority of the class will have an average performance with fewer people doing either very well or very bad, which establishes a bell shaped grade distribution.

There are several different learning styles and combinations of styles. Sarasin (1998) discusses auditory, visual, and tactile learning styles. Inquiry-Based Learning (Pasch 1991), Discovery Learning (Bruner 1966), and Expository Teaching (Ausubel 1977) are just a few other learning styles. There are several other learning styles and instruction methods. In fact, learning styles or instruction methods can overlap or be used in combination with other methods. When considering all the possibilities of instruction, it becomes clear why there is a bell shaped grade distribution in the traditional classroom. It becomes an impossible task to accommodate everyone's learning style. Therefore, instructors generally use what works best for them and on the average, most people get it, yielding a bell shaped grade distribution.

In the tutoring environment there is one instructor and one learner, which is an one-to-one relationship. This environment would appear to be an improvement on the traditional classroom because of

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the personalized attention. This may be so, but there is still the limitation of the tutor's ability to adapt to the learner's learning style. If the tutor can not adapt to the learner's learning style, then the learner does not gain very much of an advantage over the traditional classroom.

Imagine a classroom full of instructors and only one learner, which is a many-to-one relationship. Each instructor is an expert in the same field of study, but each uses a different style of instruction. Hence, the learner's chances of doing well in this classroom would appear to be significantly better than in a classroom with one instructor because each learner would adapt to the instructor(s) that would facilitate his/her learning style. In the sections that follow, we will introduce an implementation of the many-to-one relationship.

Arthur: Adapting Instruction to Accommodate Learning Style

We have developed a Web-based instruction system that provides adaptive instruction, Arthur (Gilbert 1999). Arthur takes several different styles of instruction from several different instructors and makes them available to each learner, which defines a many-to-one relationship. A group of instructors from the same field collaborate to create a course map, which is similar to a syllabus, for the course content. The course map is divided into small sections that are called concepts. A concept is a basic unit of instruction or a fundamental concept that must be covered within the course. In Figure 1, there are 3 instructors. Each instructor has their own course module, which is identified as a row. Each module utilizes a different form of instruction. For example, instructor Gilbert's module utilizes an audio based method of instruction. Notice that each instructor's module adheres to the same concept map, where concepts are represented as columns. Each module begins with concept 1 and ends with concept 4. Each cell in Figure 1 represents a concept which utilizes a different form of instruction. This information is added to Arthur via Web-based forms.

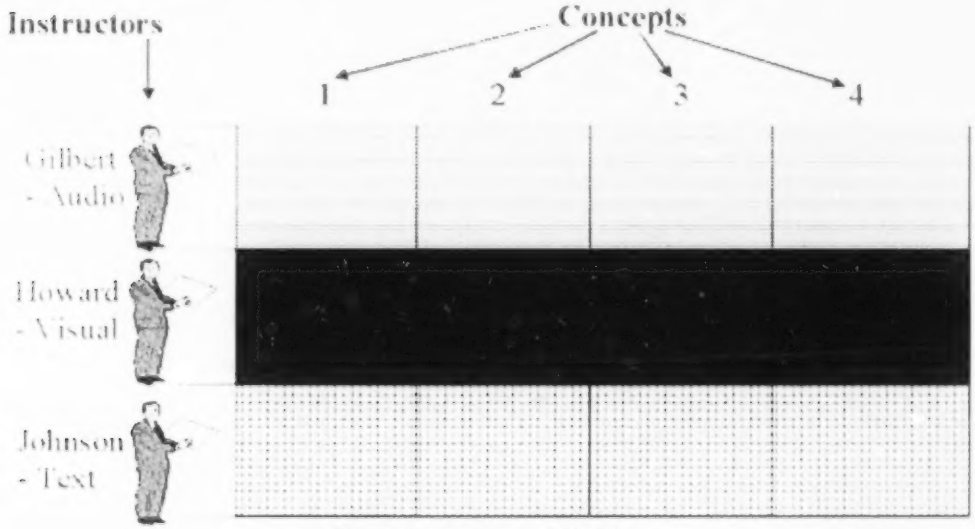

Figure 1: Concepts and Modules

Submitting Content

Instructors will add their course module to Arthur via several Web-based forms. Each instructor will deposit URLs that point to the first page associated with each concept within their module. Arthur will reference concepts via URLs submitted by the instructor. This will allow each instructor to maintain his/her own course materials on their own Web servers. Instructors will also add their personal information into Arthur as well. This includes their name, affiliation(s), email address, etc. Finally, the instructors will submit quiz questions that will appear at the end of each concept. The quiz questions appear in the form of multiple choice or written answer. Once instructors have submitted their course materials and quiz questions to Arthur, the system is ready for learner use.

Learning Experience

When a learner enters Arthur using a login and password, Arthur will deliver the first concept of one of the course modules from the instruction pool. The courses are initially selected at random. Therefore, each student will be assigned their first course module by chance. Each concept is terminated by a short evaluation quiz entered by the instructor. For example, John Smith logs into Arthur. John is assigned the first concept for Calculus 101 using an Auditory (Sarasin 1998) Expository Teaching (Ausubel 1977) style, which was developed by instructor Carl Gilbert. This style uses audio to present a general explanation of each concept followed by examples. When John completes the first concept, he will be given a short quiz. The quiz is delivered through the Web using Arthur. The quiz will be graded by the instructor, Carl Gilbert, or automatically by Arthur, i.e., multiple choice. Instructor Gilbert will be notified via email that a quiz has been taken. After notification, instructor Gilbert will log into Arthur where the quiz questions and answers will be presented. The learner's name, John Smith, is never revealed to instructor Gilbert only the question and answers. After grading the quiz, instructor Gilbert will report a score for the learner. The student must pass each section with a score of eighty percent or better in order to continue within the current course module. This evaluation method introduces the term *Mastery Learning*, which is used by Arthur to adapt the instruction style.

Adapting Instruction

Mastery Learning is based on the assumption that, given enough time and proper instruction, most students can master any learning objective (Bloom 1968 & Guskey 1986). The normal distribution of scores learners exhibit on any performance test arise from the use of one instruction style given by one instructor and the practice of holding instructional time constant for all students and allowing learning to vary. Bloom (1976) suggest that learning should be held constant and time allowed to vary. To use the mastery approach, an instructor must break a course down into small units of study, which correspond to concepts within Arthur. Each unit might involve mastering several specific concepts or objectives. Mastery usually means a score of 80 to 100 percent on a test or other assessment (Woolfolk 1998).

Arthur uses mastery learning to adapt instruction for each learner. When a learner completes a quiz at the end of a concept, Arthur employs mastery learning to adapt the instruction based upon the learner's score for each quiz. If the learner scores 80 percent or better, Arthur will allow the learner to move onto the next concept using the current course module. In the Calculus 101 example, assume John Smith passes the first concept of Carl Gilbert's course module with a score of 90 percent. Arthur will present John Smith with the second concept of instructor Gilbert's course module. John Smith scores a 70 percent on the quiz following the second concept. Arthur presents John Smith with the second concept of Frank Howard's Calculus 101 course module, which uses a different instruction style from Carl Gilbert's course module. Therefore, when learners pass the quiz at the end of a section, Arthur assumes that the instruction style used in that section matches the learner's learning style.

Learner Models using Case-Based Reasoning

When a learner successfully completes a course using Arthur, the system creates a learner model, which is a learning map, of the learner's learning experience. The learner model contains each concept that the learner passed and failed. In the cases where the learner failed the quiz at the end of a concept, Arthur

records the questions that the learner missed. The missed questions at the end of each quiz are used to classify future learners when adapting instruction. This type of classification is called *Cased-Based Reasoning*. In case-based reasoning new problems are solved by adapting or matching previously observed cases. A new problem is matched against cases in the case base and one or more similar cases are retrieved. A solution suggested by the matching cases is then reused (Reisbeck 1989 & Kolodner 1993).

For example, when John Smith completed Calculus 101, he failed the quiz following the second concept of instructor Carl Gilbert's module. John missed questions 1, 2, 4, 6, 7, 8 and 9, which are used to create a case base for John. Also, note that John was reassigned concept two under Frank Howard's Calculus 101 course module, which John passed with a score of ninety percent. Later, Chris Hudson logs into Arthur to take Calculus 101. He is assigned instructor Gilbert's course module. Chris passes concept one and fails concept two, just like John Smith. When Chris fails concept two, he misses questions 1, 2, 4, 6, 8 and 9, the same questions John Smith missed. Using the knowledge of the John Smith's case base, Arthur will classify Chris as a learner with a similar learning style as John Smith and reassign concept two to Chris using Frank Howard's course module. Because John Smith's case base for concept two is similar to Chris Hudson's new case base, Arthur assumes that Chris Hudson has a similar learning style to that of John Smith and assigns Chris an instruction method based on John Smith's case base. Classifying new learners is not the only purpose of the learner model.

The learner model is also used when previous learners return to Arthur to take a new, yet similar course. For example, if John Smith returns to Arthur to take Calculus 201, then Arthur uses John's learner model to assign John instruction methods. Given our previous examples, Arthur will assign John to instructor Frank Howard's course module because John performed best within this module compared to the other modules. If John does not perform well within instructor Howard's Calculus 201 course module, Arthur will use any previous Calculus 201 case bases to adapt instruction for John as necessary. Otherwise, Arthur will reassign concepts to John at random with an emphasis on instruction styles similar to that of instructor Frank Howard's, since John scored so well under Howard's Calculus 101 module.

The random selection of concepts within Arthur occurs when there are no previously stored case bases available for the current learner. Each course module is placed into a course module category: auditory, visual, tactile or text based. When a learner fails a quiz at the end of a concept, Arthur searches for a matching case base. If there is no matching case base available, Arthur will randomly select a new instruction method from a different course module category. The random selection of an instruction method from a different category will increase the chances that a match will be obtained. In the following sections, we will describe the system implementation of Arthur.

System Implementation

Client Side

Each learner will use Netscape Navigator 4.x or Internet Explorer 4.x to use Arthur. Once the learner goes to the Web site that hosts Arthur, the learner will be forced to authenticate using his/her pre-assigned login and password. The interface to Arthur uses a Java applet in a HTML frame to provide all the navigation information from the Web server. Special client side software requirements may be necessary for particular courses upon the demand of the instructor. For example, an instructor may require that the learner have a particular programming language installed on their computer in order to compile and test programs. Another instructor may require that the learner's computer have a particular database package or word processor. These requirements depend on the individual instructors and the tools needed to successfully complete their course.

Server Side

Arthur uses a complex knowledge base (Russel 1995) to store information and relationships on the learner, instructor, courses and the learner-instructor interactions. The knowledge base is stored in a SQL (Elmasri 1994) database on the Web server. The knowledge base consists of database tables that contain facts gathered by Arthur from the learner and instructor. It behaves as a repository of facts that can later be used during decision making, i.e. adapting instruction. The Java applet in the learner's Web browser communicates with the knowledge base through a Java socket process. This provides fast and platform

independent access to data in the knowledge repository. Arthur handles frequently asked questions using an implementation known as Intelligent FAQ.

Intelligent FAQ

Arthur will also make use of Intelligent FAQ, which is an information retrieval (Salton 1989) system used to answer frequently asked questions. When the learners are going through the course modules, questions will arise about the concept being learned. In order to answer those questions quickly and effectively, Arthur utilize Intelligent FAQ. Intelligent FAQ accepts a question from the learner and creates a query string as seen in information retrieval systems. The query string is created by removing the stop words (Britanica 1998) from the original question. After the stop words have been removed, each query string will be categorized. Arthur categorizes questions by concept and question type. Each question that is asked will be assigned a concept. In other words, the current working concept that the learner is actively pursuing will be the concept assigned to the question asked. The question types are what, when, where, why, how, define, who and other. Therefore, the query string is composed of a concept, question type and the question with the stop words removed. When a question appears for the first time, it is sent directly to the instructor via email. The instructor will log into Arthur and answer the question. Once the question has been answered, the learner will receive an email notification that an answer has been submitted. The learner will log into Arthur and pick up the answer to the question. Arthur will store the query string and answer in the knowledge base (Russell 1995) for later use. When a different learner asks a similar question, Arthur will retrieve the answer from the previously asked query string and answer stored in the knowledge base. Intelligent FAQ is being developed as part of Arthur, but can be used on any Web site.

Conclusions

The theory of learning styles states that people have different approaches to learning and studying (Dunn 1987 & Dunn 1978). Several studies show that there is "No Significant Difference" when technology is applied to instruction (Russell 1999). The most commonly used instruction environments use an one-to-many or one-to-one instructor/learner relationship. We have developed an environment that utilizes technology to deliver a many-to-one instructor/learner relationship. Before the recent use of technology, this type of education experience would have been too expensive to implement. Using the world wide Web and supporting technologies, we can deliver a many-to-one instructor/learner relationship such that individual learning styles can be accommodated.

Arthur will be initially tested using Physics 101 and CS 1, computer science programming with C++. It is expected that other domains will work as well. In the future, Arthur will add new domains of instruction. For example, the arts, sciences, languages, mathematics and other engineering disciplines will be added to Arthur. In the short term, Physics 101, which is currently being taught to various degree tracks, and CS 1 will be used to gather initial data results.

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